Glenn Research Center
Cleveland, Ohio 44135

Technical Support Package

Process To Produce Iron Nanoparticle Lunar Dust Simulant Composite

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for

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For additional information regarding research and technology in this general area, contact:

Glenn Technology Transfer Office
Mail Stop 4-2
21000 Brookpark Road
Cleveland, OH 44135

Telephone: (216) 433-3484
E-mail: *TTP@grc.nasa.gov*

Process to Produce Iron Nanoparticle Lunar Dust Simulant Composite

Brief Abstract

Simulant of lunar dust is needed when researching the lunar environment. However, unlike the true lunar dust, today's simulants do not contain nanophase iron. This disclosure describes a process to fabricate nanophase iron—lunar dust composite simulant. This process involves heating a mixture of carbon black and today's lunar simulants (mixed oxide including iron oxide) at a high temperature to reduce ionic iron into elemental iron. The product is a chemically modified lunar simulant that can be attracted by a magnet and has a surface layer whose iron concentration increased during the reaction. The iron was found to be α-iron and Fe_3O_4 nanoparticles.

Section I — Description of the Problem

Description of problem/objective: To synthesize lunar stimulants that contains iron nanoparticles. Understanding the physics, chemistry, and toxicity of the lunar regolith (the top layer of the lunar surface) in the lunar environment is essential for lunar exploration. By mass, the lunar regolith has two major components: mineral grains (dust of silicide containing mixed-metal oxides) and agglutinates (micrometeorite-impact-produced glass). It also contains numerous minor components. Among the minor components, nanometallic iron is believed to be significant. They are in and on the agglutinates, and on the mineral grains. They are chemically reactive and ferromagnetic. They really cannot be considered as "minor component" in the situations where the lunar regolith's chemical and magnetic properties need to be considered.

Simulant of lunar regolith is needed when researching the lunar environment. However, unlike the true lunar regolith, today's simulants do not contain nanophase iron. In the effort to fabricate high fidelity lunar simulants for lunar environment research and exploration, it is desirable to add iron nanoparticles to the available lunar simulant to better simulate the chemical and magnetic properties of real lunar regolith which contains iron nanoparticles.

Unique problem characteristics: Currently the process to produce high fidelity lunar simulants containing iron nanoparticles does not exist. Fabrication and storage of lunar stimulants containing iron nanoparticles is difficult because the reactivity of iron nanoparticle is high. It would be oxidized when exposed to oxygen or water. There are plans that try to mix lunar simulants and iron nanoparticles after they are made separately

Prior art: The synthesis of iron nanoparticles in carbon has been performed previously. The chemical process includes exposing a mixture of ferric chloride ($FeCl_3$) and graphite fluoride (CF_x) at 200 to 400 °C, followed by oxidation at 600 to 700 °C and reduction at 800 to 1200 °C:

$$FeCl_3 + CF_x \xrightarrow{200\text{ to }400\ ^\circ C} C(FeF_yCl_z) \xrightarrow[\text{oxidation}]{600\text{ to }700\ ^\circ C} C(FeO, Fe_3O_4) \xrightarrow[\text{reduction}]{800\text{ to }1200\ ^\circ C} C(Fe) \quad (1)$$

Where C (XX) means nanoparticles of XX embedded in carbon.

The iron nanoparticles thus produced appear to be well protected by carbon matrix. They are stable over several years.

In another previous research effort of trying to simulate the complex "space weathering" phenomena on the lunar surface, nanophase iron particles were found in vapor-deposited olivine produced by pulsed laser irradiation on an olivine sample. It simulates the reactions between micrometeorites and the lunar regolith grains that are impacted, heated, evaporated, and condensed.

Disadvantage/limitation of prior art: There are prior arts of lunar simulant production, but the simulants contain no iron nanoparticles. There are also prior arts of iron nanoparticle fabrication, but the nanoparticles are not with the lunar stimulants. The processes to fabricate lunar regolith simulants containing iron nanoparticles are not available.

Section II — Technical Description

Purpose and description of innovation: The purpose of the innovation is to fabricate simulants of lunar regolith that contains iron nanoparticles. Focus will be on the fabrication of simulants of mineral grains (dust of silicide containing mixed-metal oxides) with iron nanoparticles. Simulants of the other part of the lunar regolith (i.e., agglutinates with iron nanoparticles) was not the focus, but was detected in the product after the dust simulant was partially melted during the high temperature process.

Section III — Unique or Novel Features of the Innovation

Novel or unique features: The product and the process described in this disclosure are the first where lunar simulant that contains iron nanoparticle is successfully fabricated. To the knowledge of the investigators here, fabrication of simulants of lunar regolith with iron nanoparticles has been planned, but has not yet been fabricated successfully. Other plans try to mix lunar simulants and iron nanoparticles after they are made separately. The disclosure described here produces iron nanoparticles out of the lunar simulant (*in situ* Nanoparticle fabrication)

Despite the simplicity of this process, it is evolved from selecting and putting together knowledge and educated guess from many different areas. In addition to the knowledge of the lunar regolith and its simulant, this includes

- A previous technology of nanoparticle fabrication from graphite fluoride and ferric chloride, it is uniquely developed at NASA Glenn and has not been used elsewhere.
- a knowledge that the chemical bond will become weak when the melting point is near,
- a knowledge that the chemical bond will become weak by graphite fluoride treatment
- a parallel comparison between carbon and mixed metal oxide as matrix material that host iron,
- a belief that iron can be the only metal among the mixed oxide that will be reduced by carbon,
- another belief that the product will be in the form of nanoparticles.

Advantages of innovation

- Nanoparticles are well protected by carbon and stable in ambient air
- Lunar simulant that contains iron nanoparticles is not available today.
- The processes are simple. Iron nanoparticles can be mass- produced out of the lunar simulant with relatively few problems.
- Considering the importance of the element iron to the world, iron in the form of nanoparticles would have widespread and significant impacts that are yet to be explored.